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## LINEAR STEERING TRUCK

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### PRIORITY

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20 BACKGROUND OF THE INVENTION

## 1. Field of the Invention

The present invention relates to the field of trucks for railroad cars, and in particular, to steerable trucks for railroad cars.

## 2. The Prior Art

5           The wheels which are used on railroad trucks are, almost universally, formed with conical tapered profiles. That is, the diameters of the wheels decrease, with the portions having the smallest diameter facing outwardly, relative to the railroad car. In addition, rims, having overall diameters substantially greater than the largest diameter portion of the tapered wheel surface, are located at the innermost portions of the wheels, and placed  
10   on the truck axles and axle bearings, such that the distance between the rims of the wheels on an axle (collectively, "wheel set") is slightly less than the distance between the inside edges of the rails.

          In prior art conventional railroad trucks, the axles would be fixed relative to the truck. Typically, there would be provided two trucks situated adjacent the ends of a  
15   railroad car. Each truck is typically connected to the railroad car by a short, 14 or 16 inch diameter, cylindrical post extending downwardly from the carbody, which is received by a plate mounted generally centrally relative to the truck. The center post in such a typical prior art configuration would typically have been configured to permit a certain amount of pivoting of the truck, relative to the railroad car body. As a practical matter, the  
20   frictional forces generated by the surface contact area between the post and the plate, and the tremendous weight of the carbody, means that the amount of resistance to pivoting will be great. Thus, the friction between the truck bolster center plate and car body center bowl cause the truck to stick at any given position during travel.

However, steering forces between the wheels and rail are great enough to overcome this friction force. The steering forces cause the truck to yaw toward a position in the direction of travel. As the truck approaches the direction of travel, the steering forces decrease to a point no longer greater than the friction forces between the truck  
5 bolster center plate and car body center bowl. Since the friction forces between the plate and bowl are now greater than the steering forces, the frictions again cause the truck to stick in a position until the steering forces become great. This continuous entice energy process results in the truck never becoming truly aligned to the track. Additionally, this continuous entice energy process creates rolling resistance and wear on straight track as  
10 well as in curves.

This oscillation of the truck pivoting about the center post, describes a sinusoidal path along the track. As speed increases this phenomenon is more obvious and at higher speeds this becomes an unacceptable condition. This phenomenon is commonly called "hunting". Hunting starts at low speeds and can lead to unacceptable lateral wheel force,  
15 acceleration, and frequency unless constrained. The instability transfers rolling energy into undesirable lateral energy which creates rolling resistance, lading and car damage, and wheel and track wear.

As a railroad car having such prior art trucks would enter a curve, the rails move from under the wheels. The radius of one wheel increases as the radius of the other  
20 decreases. The different diameters creates a larger circumference on one wheel and smaller on the other. The difference in circumference causes one wheel to travel further than the other for the same revolution. The difference in travel causes the wheels and

axle to turn in the direction of the curve. Ideally, the large circumference matches the length of the outside rail and the small circumference the inside rail.

The natural tendency of a single axle wheel set, in a curve, is to assume a posture is which the axle "points" to the center of curvature of the curve. This movement of a  
5 single axle may be referred to as "going radial". In a prior art two wheel set truck with fixed axles, the axles would not be free to assume this described posture independently of one another, and the truck as a whole would be forced to rotate about the center of the truck. This condition creates high forces on the wheel sets and the truck, increases wear on the truck components, and increases rolling friction, resulting in increased fuel  
10 consumption as a result of the additional energy which had to be expended to keep the railroad cars moving. Additionally, these high forces also wear the track and the wheels.

A typical prior art truck configuration would comprise two longitudinally extending (i.e., track-wise extending) side frames, with a transversely extending bolster attached to the side frames (the "three-piece truck"). The axles of the wheel sets would be  
15 mounted fore and aft of the bolster, with the axle ends being generally fixed relative to the side frames.

Even though nominally rigidly constructed, such a truck configuration would, under sufficient loading (such as during curves), deform. Typically, this deformation would take the form of the side frames, bolster and wheel-sets skewing relative to one  
20 another to form a parallelogram, as the forces exerted on the wheels push the axles to seek yawed positions through the curve. Such parallelogramming is believed to be a common cause of railroad car derailment at low speed in curves. In rigid frame trucks this parallelogramming does not occur.

Accordingly, it can be seen that making trucks rigid and mounting them rigidly to car bodies, in an effort to eliminate hunting, and providing truck pivoting and/or flexibility, to permit truck or axle yawing or steering in curves, can and have created a design impasse for the creation of an effective three piece truck. Frame bracing of the three piece trucks helps, but still does not give a satisfactory result on wheel life and track loads.

Numerous attempts have been made to produce trucks which satisfy the requirements for efficient rolling during both straight runs and curves. Such attempts have included the provision of resilient or elastic members in the side frames and/or bolsters, pivot-mounted axles and side frames with damping apparatus like shock absorbers, and various forms of cross-bracing and the like. Such prior art configurations typically have resulted in truck structures which are costly, heavy, and/or overly complex and prone to failure or requiring extensive maintenance and replacement of components.

One such attempt is illustrated in U.S. Patent No. 5,249,530. The '530 patent discloses a steering apparatus that responds to high speed single rail vertical curve change so accurately that the truck would yaw as if it had detected a lateral curve. The car mass would continue in the original direction of travel creating high lateral force, which would lift the inside wheels from the rail. The alternating and repeated single rail vertical curves is referred to by the Association of American Rail Roads as the twist and roll regime.

To correct the problem an active lateral suspension steering system in combination with steering was conceived in U.S. Patent No. 5,666,885. In the '885 patent, the lateral suspension movement was intended to retard or add steering in lateral

acceleration regimes. The '885 invention has a prompting mechanism to facilitate turning, however the lateral suspension steering of the '885 patent is prone to high friction and not able to demonstrate the effects of steering combined with the lateral suspension.

5           Another such attempt to satisfy the requirements for efficient rolling during both straight runs and curves is illustrated in U.S. Patent No. 5,918,546. The '546 invention incorporated a low friction lateral suspension steering that through lateral acceleration retards or adds steering. Although the mechanism provided the concept, it is too complex for practical application.

## 10       SUMMARY OF THE INVENTION

          The present invention advantageously overcomes the limitations in the conventional art and prior solutions. In view of the foregoing disadvantages inherent in the known types of railroad trucks now present in the prior art, the present invention provides a new steerable railroad truck construction.

15           The general purpose of the present invention, which will be described subsequently in greater detail, is to provide a new steerable railroad truck which has many of the advantages of the prior art mentioned heretofore and many novel features that result in a new steerable railroad truck which is not anticipated, rendered obvious, suggested, or even implied by any of the prior art railroad truck devices, either alone or in  
20       any combination thereof.

          To attain this, the present invention generally comprises a truck that can be steered through curved track in an optimum manner and yet remain stable with virtually no hunting or oscillation in straight track sections. The present invention creates stiffness

through the steering mechanisms to hold the wheelsets aligned to straight and curved track and eliminates the frictions associated with hunting or oscillation. The present invention accomplishes pure rolling by utilizing low friction side bearings to support the car body, a side frame suspension to support connection of the apparatus to wheel-sets, and combined car body steering component. The present invention thus limits friction while adding stiffness to provide steering in unbalanced, balanced and overbalanced lateral curves, single rail vertical curves as well as lateral perturbations, thereby accomplishing pure rolling. In addition, the steering component constantly adjusts the axle angle of attack when track perturbations occur, thereby completely eliminating hunting.

There has thus been outlined, rather broadly, the more important features of the present invention so that the detailed description of the preferred embodiment that follows may be better understood, and so that the present contribution to the art may be better appreciated. There are additional features of the present invention that will be described hereinafter in the detailed description of the preferred embodiment and which will form the subject matter of the claims appended hereto.

In this respect, before explaining at least one embodiment of the present invention in detail, it is to be understood that the present invention is not limited in its application to the details of construction and to the arrangements of the components set forth in the following description or illustrated in the drawings. The present invention is capable of other embodiments and of being practiced and carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein are for the purpose of description and should not be regarded as limiting.

As such, those skilled in the art will appreciate that the conception, upon which this disclosure is based, may readily be utilized as a basis for the designing of other structures, methods and systems for carrying out the several purposes of the present invention. It is important, therefore, that the claims be regarded as including such  
5 equivalent constructions insofar as they do not depart from the spirit and scope of the present invention.

Further, the purpose of the foregoing abstract is to enable the U.S. Patent and Trademark Office and the public generally, and especially the scientists, engineers and practitioners in the art who are not familiar with patent or legal terms or phraseology, to  
10 determine quickly from a cursory inspection the nature and essence of the technical disclosure of the application. The abstract is neither intended to define the invention of the application, which is measured by the claims, nor is it intended to be limiting as to the scope of the present invention in any way.

These together with other objects of the present invention, along with the various  
15 features of novelty which characterize the present invention, are pointed out with particularity in the claims annexed to and forming a part of this disclosure. For a better understanding of the present invention, its operating advantages and the specific objects attained by its uses, reference should be had to the accompanying drawings and descriptive matter in which there is illustrated a preferred embodiment of the present  
20 invention.

It is therefore an object of the present invention to provide a truck which is configured to permit and accommodate the axles' natural tendency to go radial, so as to permit more efficient and less damaging rolling action in curves.

It is another object of the present invention to provide a truck which is configured to have a reduced tendency to hunt, during straight run travel, so as to reduce the damage and rolling inefficiencies associated with hunting, and in the process also increase speed capability.

5           It is a further object of the present invention to provide a truck having the characteristics sought, which has a simplified and efficient configuration.

It is an object of the present invention to achieve increased productivity by applying the concept of pure rolling at the wheel to the rail interface.

10           It is an object of the present invention to consume energy only in the direction of rolling and not divert or transfer that energy laterally or vertically.

It is an object of the present invention to achieve virtually pure rolling by controlling the angle of attack between the wheel and rail interface.

15           Thus it is another object of the present invention to control the angle of attack between the wheel and rail interface to achieve virtually pure rolling in unbalanced as well as balanced, overbalanced curves and lateral perturbations.

It is yet another object of the present invention to create stiffness through the steering mechanisms to hold the wheelsets aligned to straight and curved track.

It is still another object of the present invention to eliminate frictions associated with hunting or oscillation.

20           These and other objects of the present invention will become apparent in view of the present specification, claims and drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other additional objects of the present invention will be readily appreciated by those skilled in the art upon gaining an understanding of the preferred embodiment as described in the following detailed description and shown in the accompanying drawings in which:

5           FIG. 1 is an illustration of an elevated side view of the apparatus **10** of the linear steering truck device.

FIG. 2 is an illustration which shows an exploded side elevation view of the preferred embodiment of the apparatus **10** of a linear steering truck device of FIG. 2.

FIG. 3 is an illustration which shows a side view of apparatus **10**.

10           FIG. 4A is an illustration which shows a graphical representation of wheel set orientation and pivot points relative to the track and frame for straight track operation.

FIG. 4B is an illustration which shows a graphical representation of wheel set orientation and pivot points relative to the track and frame for curved track operation.

15           FIG. 4C illustrates the movement of the steering components during curved track operation.

FIG. 5A is an elevated perspective view of bolster **20** and the side bearings **32**.

FIG. 5B is an exploded perspective view of side bearing **32**.

FIG. 6A is an illustration which shows the alignment of a bearing adapter **50** relative to a pedestal **26**.

20           FIG. 6B is an exploded perspective view of the bearing adapter **50**.

FIG. 7 is an illustration of an equalizing side frame suspension **60a** and an exploded perspective view of one half of the components contained within housing **62**.

FIG. 8 is an exploded perspective view of aspects of the rolling universal joint 74 of the apparatus 10.

FIG. 9 is an exploded perspective view of aspects of the steering component 90 including the reactive lateral steering component 91 and the rack and pinion steering components 92 of the apparatus 10.

FIG. 10 is an exploded perspective view of aspects of the reactive lateral steering component 91.

FIG. 11 is a representation of the geometry of pivot points of the steering component 90 used to accurately steer the apparatus 10.

FIG. 12 is a depiction of the positioning of the brake beam 190.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

While this present invention is susceptible of embodiments in many different forms, there are shown in the drawings and will be described in detail herein, a preferred embodiment, with like parts designated by like reference numerals and with the understanding that the present disclosure is to be considered as an exemplification of the principles of the present invention, and is not intended to limit the claims to the illustrated preferred embodiment.

FIG. 1 is an elevated side view of the preferred apparatus 10. FIG. 2 is an exploded perspective view of the linear steering truck apparatus 10 according to a preferred embodiment. FIG. 3 is a side view of apparatus 10 along railroad tracks 11.

As shown for perspective in FIG. 4A, the linear steering truck apparatus 10 has a longitudinally extending axis 18 in the direction of travel of the apparatus 10 when it is traveling in a straight line along tracks 11. Additionally, the linear steering truck

apparatus **10** has a transverse axis **19** extending generally perpendicular to the longitudinal axis **18**. Positioned parallel to the transverse axis **19** are a first transversely extending axle **14** and a second transversely extending axle **16**, as shown in FIG. 4A. Wheels **13a** and **15a** are affixed to axle **14** forming a wheel-set **21**, as will be shown in FIG. 1. Similarly shown in FIG. 1 is another wheel-set **25** formed by wheels **13b** and **15b** being affixed to the axle **16**.

As shown in FIG. 4A, positioned generally along the transverse axis **19** at a midpoint **17** along the longitudinal axis **18** between the axles **14** and **16**, and generally parallel to axles **14** and **16** is positioned a bolster **20**, not shown in FIG. 4A. The bolster **20**, as shown in FIG. 2 and wheel-set alignment is a common configuration in railroad truck design. Typically, a bolster **20** is affixed to the wheel-sets and the car body is connected to the bolster by traditional means, including a post and bowl combination, such as are known in the art. However, the preferred embodiment does not utilize any of the traditional combinations. Instead, as shown in FIG. 1 and will be discussed in more detail in FIGS. 5A and 5B, the preferred embodiment has side bearings **32**, **34** that provide an interface between the bolster **20** and the railroad car body **12**, thereby connecting the apparatus **10** to the car body **12**.

As shown in FIG. 2, the bolster member **20** has two ends, a first bolster end **22** and a second bolster end **24**. Each bolster end **22** and **24** connects to a respective equalizing side frame suspension **60a**, **60b**. The equalizing side frame suspensions **60a**, **60b** are secured to each respective bolster end **22**, **24** by a pin joint **63a**, **63b**, as shown in FIG. 5A and discussed later in more detail. This connection allows the equalizing side frame suspensions **60a**, **60b** to rotate and carry substantially equal loads. As shown in

FIG. 2, a first equalizing side frame suspension **60a** supports a pair of pedestals **26, 27**, which are situated in the same plane parallel to the longitudinal axis **18**, as shown in FIG. 4A, and a second equalizing side frame suspension **60b** supports a pair of pedestals **28, 29**, which are situated in the same plane parallel to the longitudinal axis **18**.

5           As shown in FIG. 2 and will be discussed in more detail in FIGS. 6A and 6B, each pedestal **26, 27, 28, 29** engages an axle bearing **30** by being formed to rest on a bearing adapter **50**, which in turn rests on an axle bearing **30**. The axle bearing **30** is formed to fit around one end of an axle **14, 16**. This configuration permits the connection of the wheel-sets **21, 25** to apparatus **10** and car body **12**, not shown. As shown in FIG. 2  
10       and will be discussed in more detail in FIG. 9, in the preferred embodiment each pedestal **26, 27** and **28, 29** movably attaches to another pedestal **26, 27** and **28, 29** by a steering component **90** and equalizing side frame suspension **60a** and **60b**. The steering component **90** also provides the preferred means for performing car body steering.

FIGS 5A and 5B depict the preferred means for attaching the apparatus **10** to the  
15       car body **12**. As shown in FIG. 5A, a railroad car body **12**, represented as hatched lines, can be mounted to the linear steering truck apparatus **10** by resting a car body bolster of the car body **12** onto a plurality of side bearings **32, 34**. As shown in FIG. 5A, a side bearing **32, 34** is placed proximate to each end of the bolster **22, 24**. As shown in FIG. 5B, which is an exploded perspective of side bearing **34**, the preferred side bearing **34**,  
20       contains three conical rollers **35, 36, 37** situated between the plates **31** and **33**. Plate **31** is preferably formed as part of the bolster **20**, as shown in FIG. 5A. Alternatively, the plate **31** can be formed and rested on the bolster **20**, or alternatively, the plate **31** can be affixed to the bolster **20** by conventional means, such as a bolted connection. Although use of

the side bearing **32, 34** is the preferred embodiment, the steering mechanisms of the apparatus **10** will perform as intended when traditional car body mounting is used.

In the preferred embodiment as shown in FIG. 5A, rollers **35, 36, 37** each have interconnecting teeth **35a, 36a, and 37a**, respectively. As shown in FIG. 5A, teeth **35a, 36a, 37a** interlock with teeth **31a and 33a**, thereby timing the rollers **35, 36, 37** between plates **31 and 33** and preventing unwanted rubbing and friction. In the alternative, a spacer (not shown) may be employed to prevent contact of the rollers **35, 36, 37** to each other thereby eliminating additional friction points.

When the car body **12** is placed on the side bearings **32, 34**, as shown in FIG. 5A, the center plate post (not shown) of the car body **12** is fitted into the through hole **42** in the bolster **20** in order to center the car body **12** onto the linear steering truck apparatus **10**. The through hole **42** of the bolster **20** thus takes only longitudinal and lateral loads, while the side bearings **32, 34** support the vertical load of the car body **12**. As compared to conventional car body attachment set-ups, as discussed above, the use of side bearings **32, 34** is a light weight design that decreases friction by eliminating turning resistance and wear and by providing a steering connection to the car body **12**. Moreover, the preferred construction, where the car body mass is supported by side bearings **32, 34** located at near the edges of the bolster **10**, uniquely directs the car body load path equally through the entire bolster **10**. In the preferred embodiment, the side bearings **32, 34**, bolster **20** and pedestals **26, 27, 28, 29** are made of a high strength ferrous casting, although a high strength material of similar strength may be used. In the preferred embodiment, the conical shape of the rollers provides ideal radial rolling with little or no friction.

As shown in FIG. 2, an axle bearing **30** is fitted around one end of an axle **14**, **16** of a wheel-set **21**, **25**. The axle bearing **30** can be a conventional rail axle bearing structure, such as the cylindrical axle bearing **30** as illustrated. As shown in FIGS. 2, 6A and 6B, the bearing adapter **50** is formed to rest on an axle bearing **30**. In turn, each pedestal **26**, **27**, **28**, **29** is formed to rest on a bearing adapter **50**, thereby connecting the apparatus **10** to the wheel-sets **21**, **25**.

As shown in FIG. 6A, the bearing adapter **50** is preferably constructed of an outer race **52**, assembly springs **43**, **44**, **45**, **47** (not shown in FIG. 5), a ball bearing cage assembly **56**, and an inner race **58**. The outer race **52** has a spherical interface providing vertical centering alignment of the pedestal **26** about the center of rotation of the axle bearing **30**, as shown in FIG. 6A. As shown in FIG. 6A, the pedestal **26** has a pedestal jaw **54**, which is preferably a standard jaw interface and which movably attaches the pedestal **26** to bearing adapter **50**. Preferably, the bearing adapter **50** is formed to receive the pedestal jaw **54**. Preferably, the bearing adapter **50** is formed in a tapered fashion and formed to have a female portion to receive the male pedestal jaw. The connection retains the bearing adapter **50** within the pedestal **26** both longitudinally and laterally. Tapered clearance is provided at the jaw interface in order to allow the bearing adapter **50** to yaw and roll with the pedestal during lateral, vertical and steering movement.

The outer race **52** provides vertical load transfer from the pedestal **26** to the axle bearing **30**. The inner race **58** has a formed spherical interface for connection with the axle bearing **30**, thus allowing the pedestal **26** to pivotably attach to the wheel-set **21**. As shown in FIG. 6B, an exploded perspective of bearing adapter **50**, a top spacer **51**, a bottom spacer **53**, a cage **55**, a plurality of ball bearings **57**, and assembly fasteners **59**

form the ball bearing cage assembly 56 in FIG. 6B. An assembly fastener 59 is preferably a ¼ inch screw and nut, although any fastening device may be used. The cage 55 and the ball bearings 57 are placed between the top 51 and bottom 53 spacers, and the assembly fasteners 59 connect the top 51 spacer to the bottom 53 spacers. Once the bearing adapter 50 is placed under load, the cage 55 and ball bearings 57 are sealed from contamination. The ball bearing cage assembly 56 is centered on the plurality of ball bearings 57 and retains them in their respective location. The ball bearing cage assembly 56 is situated between the outer race 52 and inner race 58, and preferably four assembly resilient members 43, 44, 45, 47 attach the outer race 52 to the inner race 58. The use of the assembly resilient members 43, 44, 45, 47 are preferably necessary only for assembly of the bearing adapter 50 and to allow for rotational freedom in operation.

This preferred assembly of the bearing adapter 50 allows yaw and roll freedom of the wheel-sets 21, 25 and pedestals 26, 27, 28, 29 while holding the bearing adapter 50 together. The spherical bearing adapter 50 can be machined to fit any standard axle bearing. The apparatus 10 thus absorbs lateral and longitudinal loads while allowing for yaw and roll freedom of the wheel-sets 21 and 25. Additionally, the bearing adapter 50 provides a normal force on the axle bearing 30 for all load conditions and eliminates moment on the axle bearing 30 thereby leading to longer life of the axle bearing 30.

The inner race 58 and outer race 52 are preferably made of a high strength ferrous casting, although a high strength material of similar strength may be used. The cage 55 is preferably made of steel. The top spacer 51 and bottom spacer 53 are preferably made of ultra-high molecular weight, high temperature polyethylene. The use of plastic for the construction of the top spacer 51 and bottom spacer 53 permits the weight of the car body

12 to elastically compress the plastic to form a seal around the plurality of ball bearings 57 thereby sealing the ball bearings 57 from the outside environment. In the preferred embodiment, there are twenty-two (22) one and one-half (1 ½) diameter inch steel ball bearings 57, although any quantity of ball bearings of the diameter sufficient to carry the  
5 vertical load may be used.

In addition to each pedestal 26, 27, 28, 29 being engaged to an end of a transversely extending axle 14 and 16, each pedestal 26, 27, 28, 29 is also movably attached to another pedestal 26, 27, 28, 29, as shown in FIG. 1. Each pedestal 26, 27, 28, 29 is movably attached to another pedestal 26, 27, 28, 29 located in the same plane  
10 parallel to the longitudinal axis 18, as shown in FIG. 4A. As shown in FIG. 2, each pedestal 26, 27, 28, 29 is preferably movably attached to another pedestal 26, 27, 28, 29 by an equalizing side frame suspension 60a, 60b and steering component 90.

In the preferred embodiment, and as detailed in FIG. 7, an equalizing side frame suspension 60a has a housing 62. A housing 62 is placed within a groove 61 created  
15 between a first plate 65 and second plate 67, and a groove 61 is located proximate each end 22, 24 of the bolster 20, as shown in FIG. 5A. The first plate 65 and second plate 67 each have an orifice 71 and 73 respectively. As shown in FIG. 7, the housing 62 has an orifice 156 and the orifice 156 is aligned with orifice 71 and orifice 73 such that a passage is formed. This arrangement allows for a pin 63a, b, as shown in FIG. 5A, to be  
20 placed within this passage to connect the housing 62, and therefore the equalizing side frame suspension 60a, to the bolster 20, as shown in FIG. 1. In FIG. 7, one half of a housing 62 is cut-away and the elements contained therein are exploded for better illustration. For ease of discussion, only one half of the elements that make up the

equalizing side frame suspension **60a** and associated housing **62** are discussed. One skilled in the art would understand that a substantially identical arrangement of elements are present within the other half of the equalizing side frame suspension **60a** and associated housing **62**.

5           As illustrated in FIG. 7, one half of a housing **62** preferably contains a rear suspension lug **64**, a resilient member **66**, a viscous damper **68**, and a spring and damper lug **70**. One half of an equalizing side frame suspension **60a** also has a non-linear force equalizer **72**, and a rolling universal joint **74**. The rear suspension retainer lug **64** is preferably cast as part of the housing **62** and contains an orifice **78**, positioned generally  
10       perpendicular to the passage created by orifices **156**, **71** and **73**, not shown in FIG. 7, and opens into a space within orifice **156**. One end of a resilient member **76** is positioned to abut the lug **64**, whereby the lug **64** holds the resilient member **66** in place. The viscous damper **68** is then preferably placed within the resilient member **66**. The viscous damper **68** has a cyclical retainer **150** that is positioned through the lug orifice **78** and into the  
15       space within orifice **156**. The cyclical retainer **150** has an orifice **152** that aligns with the passage created by orifices **156**, **71**, and **73**. As stated above, a pin **63a** or **63b** as shown in FIG. 5A, can then be placed within the passage created by orifices **156**, **71**, **73** and **152** to connect the bolster **20** to the equalizing side frame suspension **60a** and associated components, as shown in FIG. 1.

20           The viscous damper **68** is preferably a tunable hydraulic damper. The viscous damper **68**, a portion of which is cut-away in FIG. 7, has a check valve **154**, which preferably has a flow control orifice that can be adjusted dependant on ride requirements. The preferred check valve **154** is preferably a screw with a flow control orifice, which

extends from the exterior, through the piston **155** of the viscous damper **68** into the internal cylinder of the viscous damper **68**. Varying the size of the flow control orifice adjusts the ride requirements, which may be based on the weight of the car body and lading, speed requirements, track conditions and centers of gravity.

5           The plunger arm **153** of the viscous damper **68** has an orifice **79**. The plunger arm **153** is positioned through an orifice **77** of the spring and damper lug **70**. The lug **70** is positioned to retain a second end **75** of the resilient member **66**. The lug **70** has first plate **160** and second plate **162**, each having an orifice **164** and **166** respectively. The orifice **79** of the plunger arm **153** is aligned with orifices **164** and **166** forming a passage.

10       A first end **82** of the non-linear force equalizer **72** has a pair of orifices **146** and **147** that are positioned to align with the passage formed by orifices **79**, **164**, and **166**. A pin **81** is placed within the passage formed by orifices **79**, **164**, **166**, **146** and **147**, thereby movably connecting the viscous damper **68**, non-linear force equalizer **72** and spring and damper lug **70**, as well as associated components.

15           As will be shown in more detail in FIG. 8, a second end **83** of the non-linear force equalizer **72** preferably has a rounded saw tooth face **830a** for movably connecting to an opposing rounded saw-tooth face **830b** of the rolling universal joint **74**, thereby interlocking the non-linear force equalizer **72** and rolling universal joint **74** and allowing for rocking movement. The second end **85** of the rolling universal joint **74** preferably has  
20       a rounded saw-tooth face **850a** that movably connects to opposing rounded saw-tooth faces **850b** of the pedestal **26**, thereby interlocking the rolling universal joint **74** to the pedestal **26** and allowing for a rocking movement.

As shown in FIG. 7, the non-linear force equalizer 72 has an orifice 170 that aligns with orifice 172 of the housing 62 forming a passage. A pin 174 is then placed within this passage to pivotably mount the non-linear force equalizer 72 to the housing 62. This configuration of the equalizing side frame suspension 60a provides for substantial equalization of load at each wheel 13a, 13b connected to pedestals 26, 27 and further provides for absorbance of vertical bounce energy experienced by the wheels 13a, 13b, 15a, 15b and pedestals 26, 27, 28, 29, as shown in FIG. 1.

In the preferred embodiment, and as shown in FIG. 8, the rolling universal joint 74 contains a top section 86, a bottom section 87, an inner section 88, and assembly resilient members 89. The inner section 88 has a gear-face 880a for connecting to an opposing gear face 880b of the top section 86, which allows for an interlocking connection. Additionally, the inner section 88 has a gear face 870a for connecting to an opposing gear face 870b of the bottom section 87, which allows for an interlocking connection. This interlocked connection allows lateral movement of the rolling universal joint 74. Assembly resilient members 89 are preferably springs that connect the top section 86 to the bottom section 87. As shown in FIG. 8 the rounded interlocking connection of the top section 86 to the second end 83 of the non-linear force equalizer 72 and the rounded interlocking connection of the second end 85 of the rolling universal joint 74 to opposing rounded saw-tooth face 850a of the pedestal 26 provides for longitudinal movement of the rolling universal joint 74. In the preferred embodiment, the housing 62, rear suspension retainer lug 64, spring and damper retainer lug 70, non-linear force equalizer 72 and rolling universal joint 74 are preferably constructed of a high

strength ferrous casting, although a high strength material of similar strength may be used.

As shown in FIG. 4C, the preferred means for performing car body steering is accomplished through use of a pair of steering components **90a**, **90b**. FIG. 9 details more greatly a steering component **90**. For discussion purposes, only one steering component **90** will be discussed. A steering component **90** preferably has a reactive lateral suspension steering component **91** and rack and pinion steering component **92** as shown in FIG. 2. As shown in FIG. 9, the rack and pinion steering component **92** is comprised of a gear tray **94**, which is preferably formed as part of bolster **20**, a pinion **96**, an idler **98**, and a plurality of racks **100**, **101**, **102**. The idler **98** slides over a pinion recess **106** of the pinion **96**. The combined idler **98** and pinion **96** rest on the gear tray **94**, where the idler **98** rests within recess **104**. This configuration allows the idler **98** to rotate freely about recess **106**. The aperture **980** of idler **98** provides freedom of movement about recess **106** of pinion **96**.

As shown in FIGS. 2 and 9, rack **100** engages and rests on the gear tray **94**, rack **101** engages and rest on the pinion **96**, and rack **102** engages and rests on the idler **98**. The racks **100**, **101**, and **102** engage respectively gear teeth **200**, **201**, **202** of gear tray **94**, pinion **96**, and idler **98**, and running tooth clearance is established by providing a rolling surface between the gear teeth **200**, **201**, **202**. In the preferred embodiment, the gear tray **94**, pinion **96**, idler **98**, and racks **100**, **101**, and **102** are preferably constructed of a high strength ferrous casting, although a high strength material of similar strength may be used.

As shown in FIGS. 4C and 9, a steering component **90** rotatably attaches to a pair of pedestals **26, 27** permitting pivotal movement about the first pedestal attachment point **110a, 110b** when the first pedestal **26** rotatably attaches to the rack **101** on the pinion **96**, and permitting pivotal movement about the second pedestal attachment point **111a, 111b** and third pedestal attachment point **112a, 112b** when a second pedestal **27** rotatably attaches to the rack **100** on the gear tray **94** and to the rack **102** on the idler **98**. The steering component **90** rotationally attaches to the apparatus **10** when a ball bearing **97** of the pinion **96** attaches through an opening in the bolster **20** to a receptive orifice **180** within plate **33** of the side bearing **32**.

As shown in FIG. 4B, as a rail **11** turns out from under the car body **12**, not shown, wheel-sets **25** and **21** naturally yaw due to the cone shape of wheels **13b, 15b** and **13a, 15a**. Simultaneously, each steering component system **90a, 90b** moves in the direction of the turn, thereby accurately steering each axle **14, 16**. As shown in FIG. 4C, pinion **96a** is allowed to rotate as well as translate across the bolster **20**. The rotation of pinion **96a** through rack **110a** pulls pedestal **26** and wheel **13a** to controlled alignment to the curve. The rotation of pinion **96a** also translates pinion **96a** across the bolster **20**. The translation pulls and yaws bolster **20**. Bolster **20** attachment through rack tray **94** and rack **100a** pull pedestal **27** and wheel **13b** to controlled alignment to the curve. The pinion **96b** also creates rotate and translations in a direction opposite of pinion **96a**. Thus, the rotation of pinion **96b** pushes rack **110b**, pedestal **28** and wheel **15a** to controlled alignment to the curve. The rotation of pinion **96b** also translates pinion **96b** across the bolster **20**. The translation pushes and yaws bolster **20**. Bolster **20** attachment through rack tray **94** and rack **100b** pushes pedestal **29** and wheel **15b** to controlled

alignment to the curve. Thus, entering the turn, pedestals **26, 27** and attached wheels **13a, 13b** have the effect of being pulled together on the one side, represented by arrows **A** and **A'**, and pedestals **28, 29** and attached wheels **15a, 15b** have the effect of being pushed apart, represented by arrows **B** and **B'**. However, as will be shown, although each steering component system **90a, 90b** is rigid and thereby retards the amount of movement of pedestals **26, 27, 28, 29**, each steering component **90a, 90b** simultaneously allows apparatus **10** to achieve pure rolling while decreasing the amount of friction generated.

As will be shown, the center of the car mass is located along pinions **96a** and **96b**. The wheelsets **21** and **25** are higher above track **11** than the pinions **96a** and **96b**. Since the pedestals **26, 27, 28, 29** are connected at these points and are allowed to swing, the pedestals act as a pendulum using the force of the mass of the car **12** acting on apparatus **10** to restore and center apparatus **10** above the track **11**. Thus, a reactive lateral suspension steering component **91a, 91b** of each steering component **90a, 90b** uses this pendulum effect as a restoring force to always return the apparatus **10** back substantially to centering alignment. As shown in FIG. 11, the geometry of points from axle **14** to points **111a, 111b** on the bolster **20** forms a trapezoid and the geometry of points from axle **16** to points **110a, 110b** on the bolster **20** forms a parallelogram. The reactive lateral suspension steering component **91a, 91b** pivotably connects pedestals **26, 27, 28, 29** thereby allowing a lateral force at one axle **14** to be reacted by the other axle **16**. Thus, once the trapezoid side yaws, axle **14** of apparatus **10** steers to the center of the track regardless of which end of the apparatus **10** is leading.

FIG. 10 is an exploded perspective of a reactive lateral suspension steering component **91** and details more greatly the component **91**. The reactive lateral

suspension steering **91** has a selector housing **120**. A pin **130** is preferably used to secure the selector housing **120** to the bolster **20**. Preferably, pin **130** is placed within orifice **143** of the housing and an orifice in the bolster **20**, not shown. As shown in FIG. 10, the selector housing **120** has a pair of selectors **121**, **122** attached, which contain opposing gear faces **123**, **126** that allow the selectors **121**, **122** to pivot within the selector housing **120**. The selectors are attached by pins **140**, **141** being placed through selector orifices **137**, **138** and housing orifices **142a**, **142b**. The reactive lateral suspension **91** further has a plurality of struts **124**, **125**, where each strut **124**, **125** is movably attached to a selector **121**, **122** by ball joints **131**, **132** placed through selector orifices **133**, **134**. A strut **124**, **125** of the reactive lateral suspension **91** has a ball joint **127**, **129** which movably attaches each strut **124**, **125**, preferably by ball joints and cap screws to a wheel-set bearing **128** of the pedestals **26**, **27**, as shown in FIGS 3. In this preferred arrangement, the wheel-set bearing **128** is located above the pinion **96**. As discussed above, pinion **96** represents the center of the car body mass and acts as a pendulum between the attached pedestals **26**, **27**, **28**, **29**. The selectors **121**, **122** bottom against the back of the selector housing **120** to interlock the wheel-set **21**, **25** to limit lateral movement and provide rigidity to the apparatus **10**.

As is shown, each reactive lateral suspension steering component **91a**, **91b** of the apparatus uses the pedestals **26**, **27**, **28**, **29** for swing hangers, allowing the bolster **20** to work as a pendulum, thereby centering the car mass between the wheel-sets **21**, **25**. The car body steering utilizes the pedestals **26**, **27**, **28**, **29** to detect and correct overbalance, unbalanced curves such as single rail vertical curvature and lateral wheel-set acceleration associated with hunting. The connection between the wheel-sets **21**, **25** and bolster **20**

also turns the wheel-sets **21, 25** away from any unbalanced curve. In the preferred embodiment, selector housing **120**, selectors **121, 122**, and struts **124, 125** are preferably constructed of a high strength ferrous casting, although a high strength material of similar strength may be used.

5           The struts **124, 125** also have brake guide brackets **144, 145** that provide for positioning of a brake beam **190**. A brake guide bracket **145** is the preferred means for maintaining full brake shoe contact on a wheel when brakes are applied. As shown in FIG. 12, the brake beam **190** slides into the guide bracket **145**. The positioning allows for an attached brake shoe **192** to rotate about the ball joints **129** and **132**, as shown in  
10   FIG. 12, during steering. Thus, when the brakes are applied, brake shoe **192** slides up the guide bracket **145** and is allowed to rotate about ball joints **129** and **132** for full brake shoe **192** contact on the wheel (not shown). This action allows the brake envelope to maintain a constant position relative to a wheel thereby saving brake shoe life.

          The apparatus as described herein has demonstrated reduced energy consumption.

15   Resistance tests were conducted using a loaded 100 ton open hopper car. The tests were conducted using the Train Resistance test methods established for the AAR's "Energy Program." The loaded car body steering truck rolling resistance was 1.0 pound per ton (lbs/ton) of car weight on straight track and added only 0.1 pound per ton of car weight per degree of curvature for curved track. The track foundation flexibility creates  
20   resistance to rolling. The track deflection and sub-grade soil dampening have a rolling resistance of 0.8 to 1.0 lbs/ton. By subtracting the track foundation resistance from the truck rolling resistance, it is determined that the car body steering truck was within 0.2 to 0.00 lbs/ton of achieving pure rolling.

The means for performing car body steering aligns the wheel-sets for straight and all degrees of track curvature. The steering geometry establishes an average angle of attack between the wheel and rail of less than one mil-radian (0.057 degrees) on straight or curved track. Lead axle displacement was measured to determine the angle of attack as it progressed through a 12 degree curve. The lead axle displacement is zero angle of attack on tangent track. The lead axle displacement follows the spiral curve entry to ideal displacement or zero angle of attack for the constant radius portion of the curve. The lead axle displacement follows the spiral curve exit out of the curve to zero angle of attack back to tangent track. The steering mechanism governs the axle displacement and steering force. The measured steering force showed minimal force required to follow the track with no wheel slippage which indicates no tread wear.

As described above, in the preferred embodiment, many components of apparatus 10 are constructed of high strength ferrous casting using the lost foam process, although a high strength material of similar strength may be used. The use of the lost foam process to construct the component parts permits the parts to provide an ideal load path as well as minimizing overall weight.

The use of this material and process makes the apparatus 10 light weight, yet high strength. By creating the apparatus 10 out of high strength ferrous casting, the weight of the apparatus 10 has been reduced approximately 1,000 lbs. per truck as compared to conventional three piece trucks.

While the invention has been described in connection with a preferred embodiment, it will be understood that it is not intended that the invention be limited to that embodiment. On the contrary, it is intended to cover all alternatives, modifications

and equivalents as may be included within the spirit and scope of the invention as disclosed.

As to the manner of usage and operation of the present invention, same should be apparent from the above disclosure, and accordingly no further discussion relevant to the manner of usage and operation of the present invention shall be provided.

With respect to the above description then, it is to be realized that the optimum dimensional relationships for the parts of the present invention, to include variations in size, materials, shape, form, function and manner of operation, assembly and use, are deemed readily apparent and obvious to one skilled in the art, and all equivalent relationships to those illustrated in the drawings and described in the specification are intended to be encompassed by the present invention.

Therefore, the foregoing is considered illustrative of only the principles of the present invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the claims to the exact construction and operation shown and described, and accordingly, all suitable modifications and equivalents may be resorted to, falling within the scope of the claims.